Minntronix Technical Note

Common-Mode Choke Inductance:

Not Always The Most Critical Spec

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Common-mode Choke Inductance

- Most magnetics manufacturers (including Minntronix) specify the inductance of a common-mode choke, usually as a minimum value

- While a common-mode choke's inductance is relevant to it's performance it isn't the **only** relevant parameter

- Two other factors place a significant role in CMC performance: core loss and distributed capacitance

Part 1: How common-mode chokes work

Common-mode Signal:

A signal which appears as a voltage on a pair of conductors having the same phase and polarity on each conductor with respect to ground.
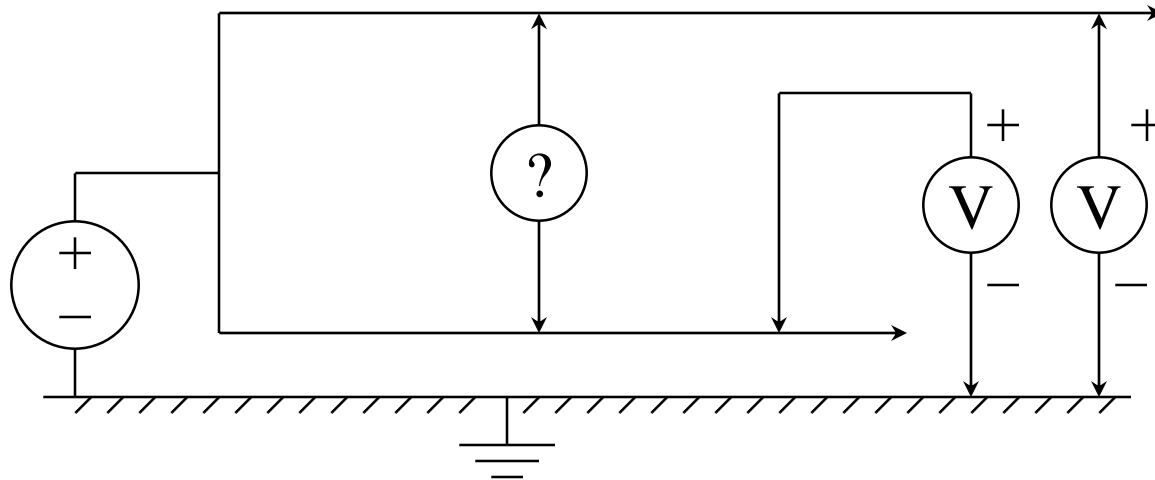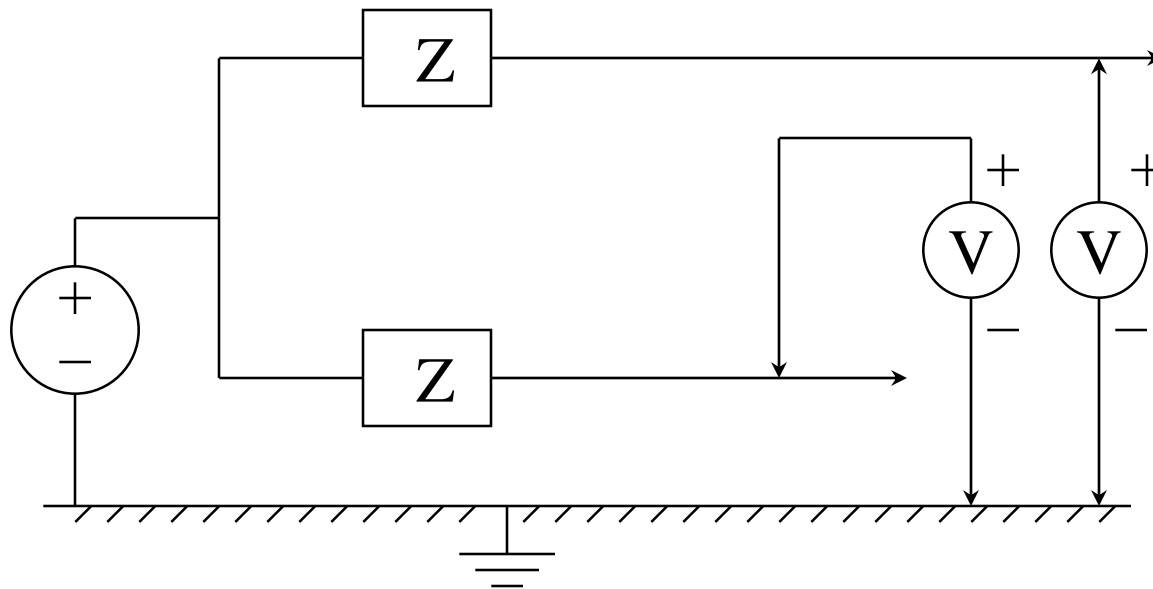
Common-Mode Chokes

Common-mode interference becomes a
differential signal by becoming unbalanced:

Radio, power line or adjacent signal wire interference
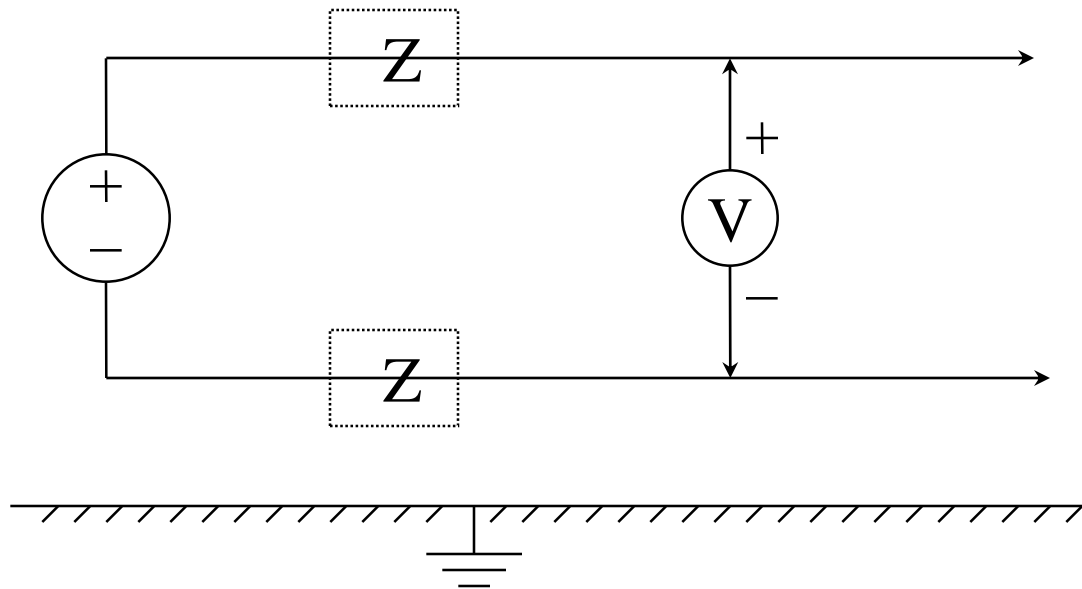
Capacitive effects count, too.
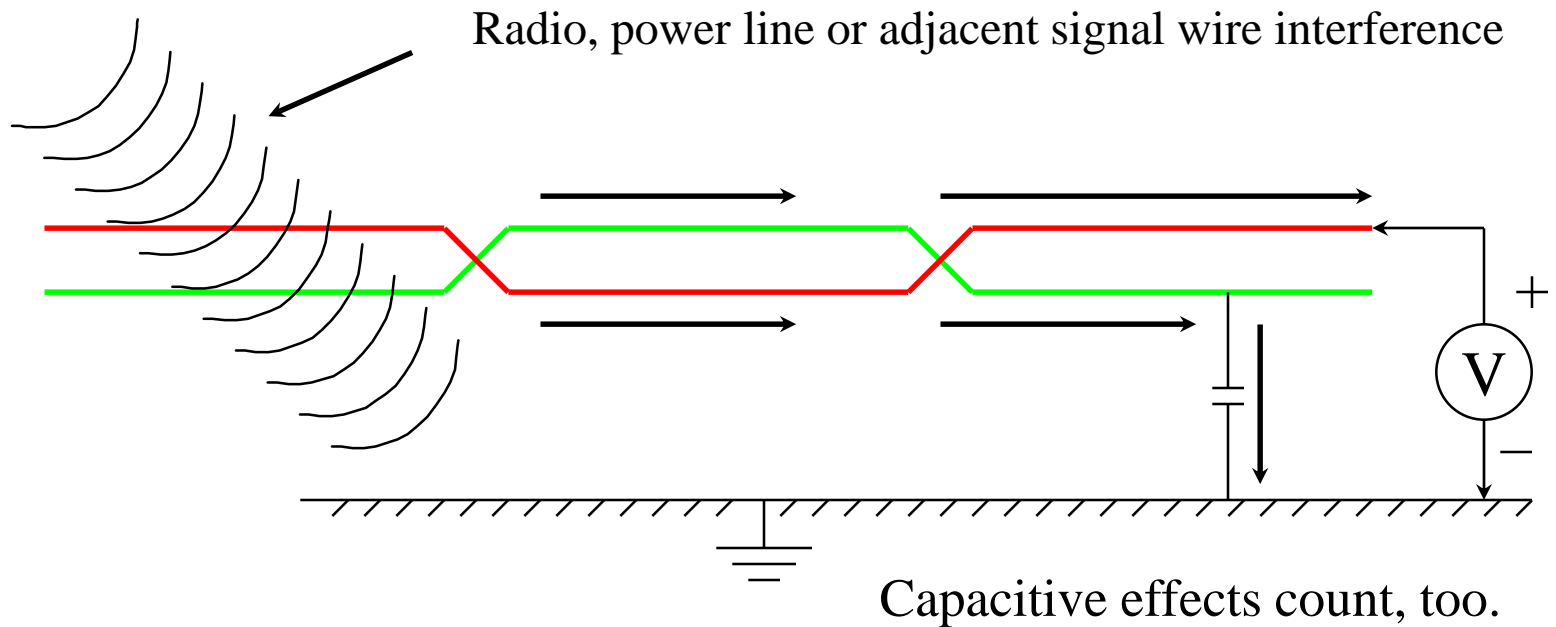
Common-Mode Chokes

We need a special device: one that opposes common-mode signals,
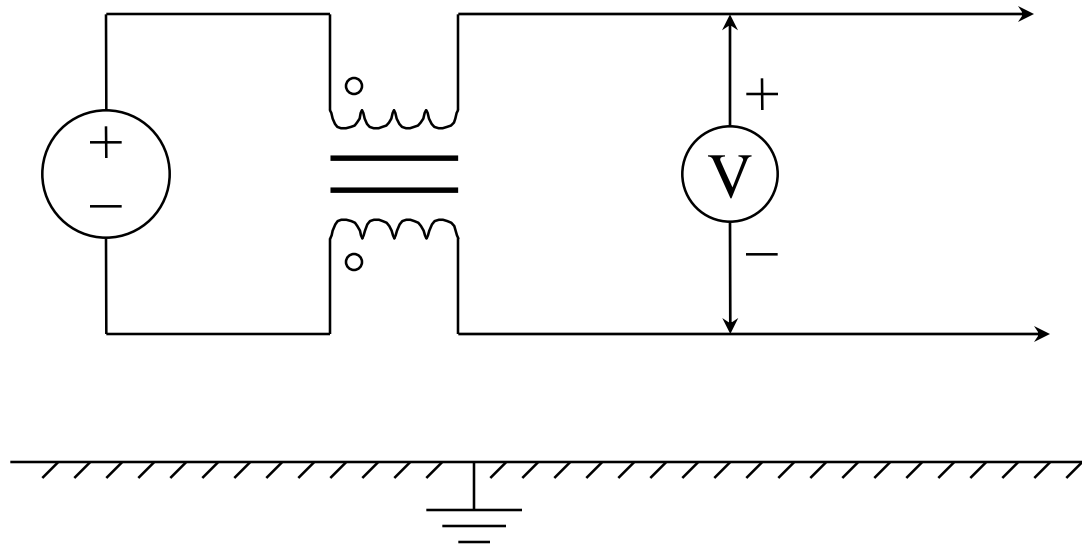
Common-Mode Chokes

We need a special device: one that opposes common-mode signals, but doesn't impair differential signals.
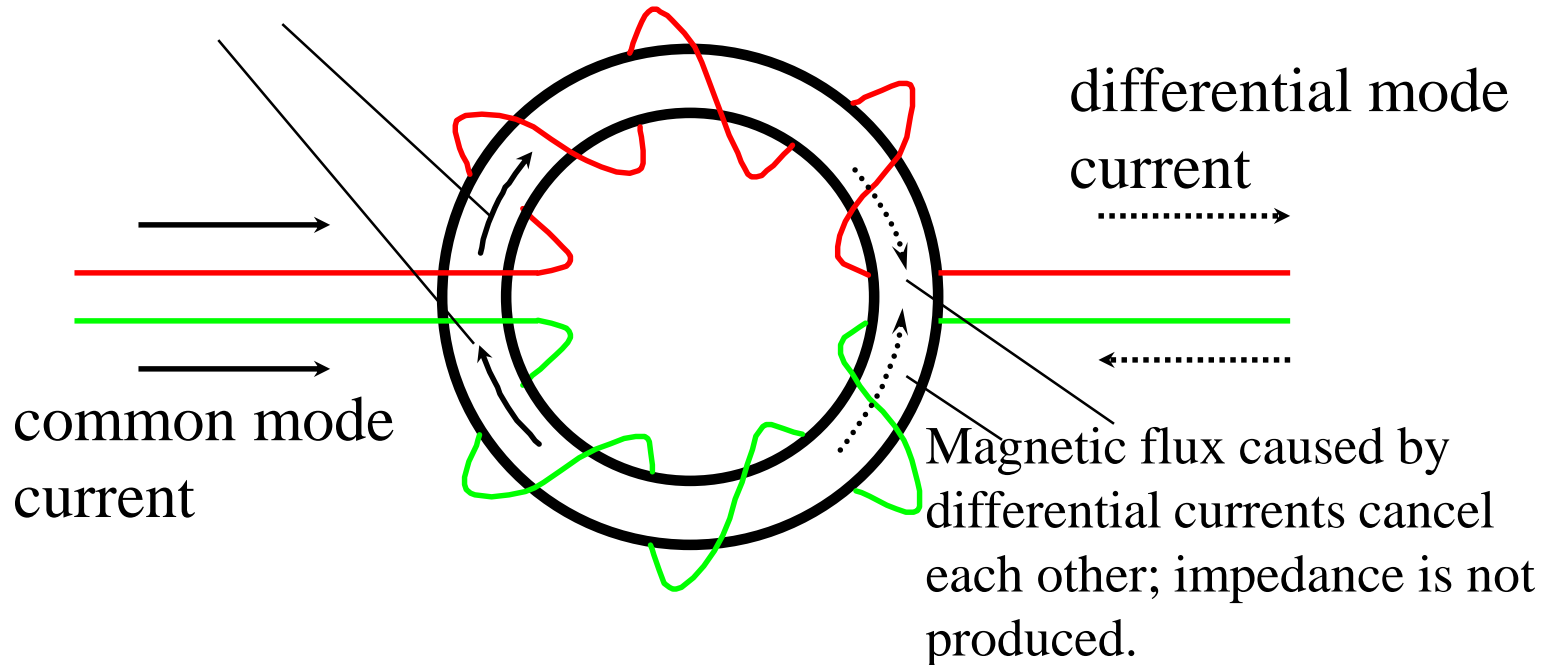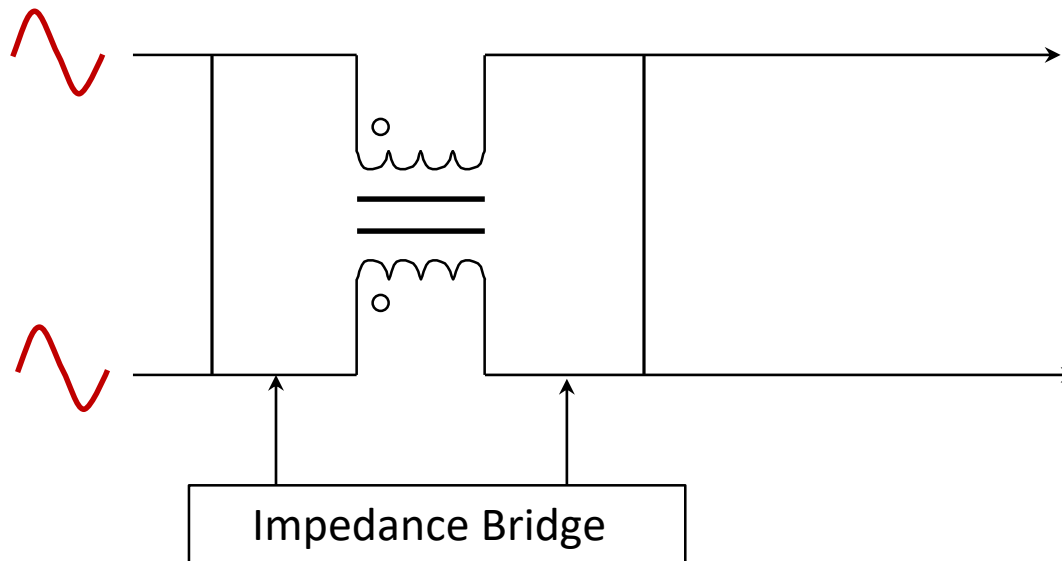
Common-Mode Chokes

Solution:

The Common-mode Choke

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Common-Mode Chokes

Magnetic flux caused by common mode current adds up, producing an opposing impedance.

differential mode current

common mode current

Magnetic flux caused by differential currents cancel each other; impedance is not produced.

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Part 2: Testing common-mode chokes

Since a common-mode signal appears at both 'dotted' terminals of the CMC they are at equal potential and may be connected together:

Impedance Bridge

We can directly measure the impedance to the common-mode signal by connecting to both windings in parallel
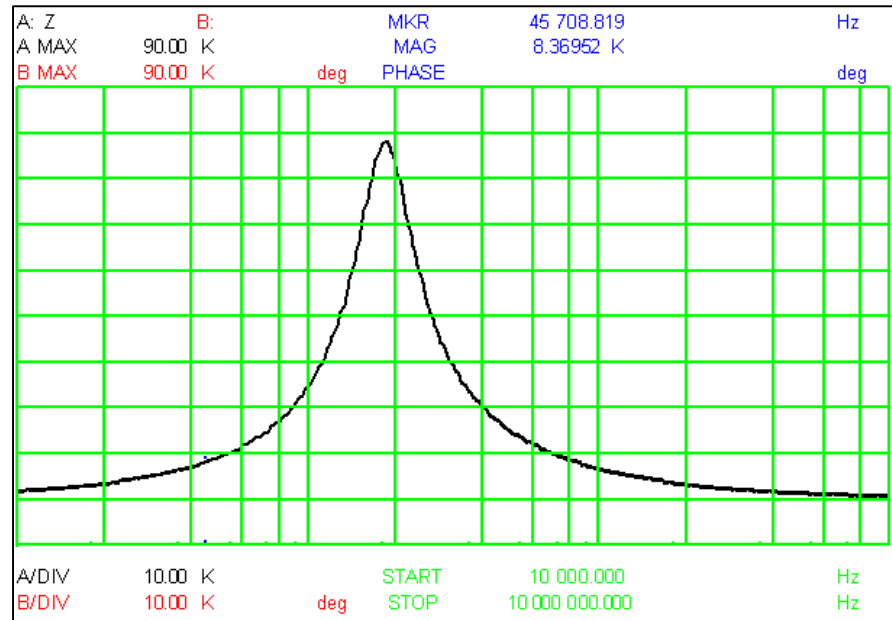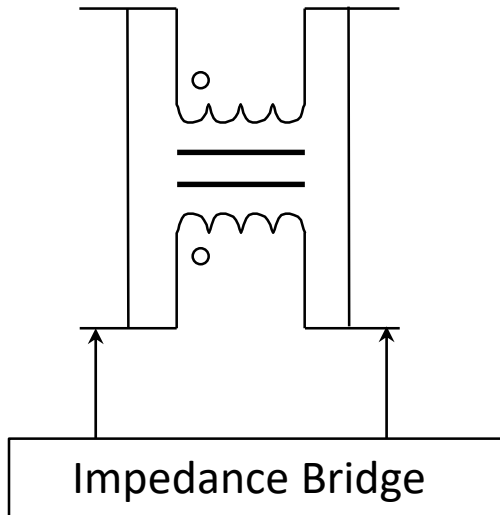
Part 2: Testing common-mode chokes

Side note: Why do we need to connect both windings in parallel? If both windings aren't connected to the impedance bridge the distributed capacitance from the unconnected winding will reflect back into the winding being measured.

Impedance Bridge

CMC with both windings connected

CMC with only one winding connected
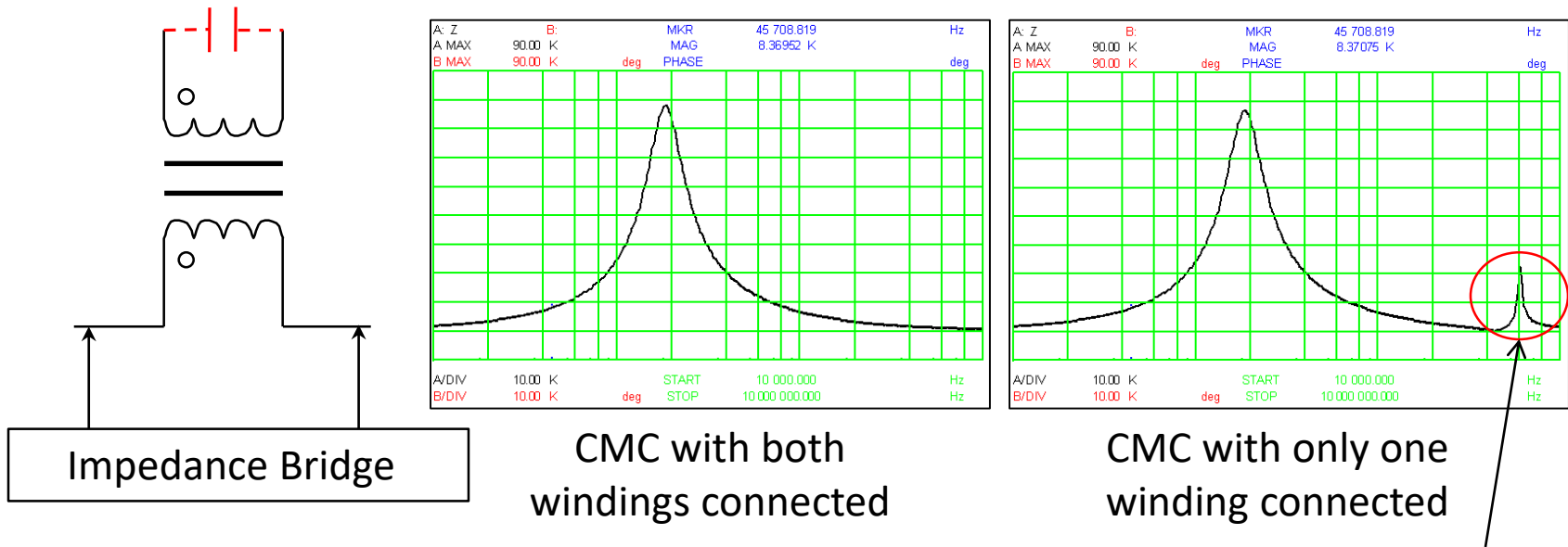
This results in a second resonance above the main CMC's resonant frequency.

Part 2: Testing common-mode chokes

Proper testing of a common-mode choke is done with both (or all if 3-phase) windings connected in parallel as shown below.

Impedance Bridge

A: Z		B:	MKR	45 708.819	Hz
A MAX	90.00 K		MAG	8.36952 K	
B MAX	90.00 K	deg	PHASE		deg

A/DIV	10.00 K		START	10 000.000	Hz
B/DIV	10.00 K	deg	STOP	10 000 000.000	Hz

CMC with both
windings connected

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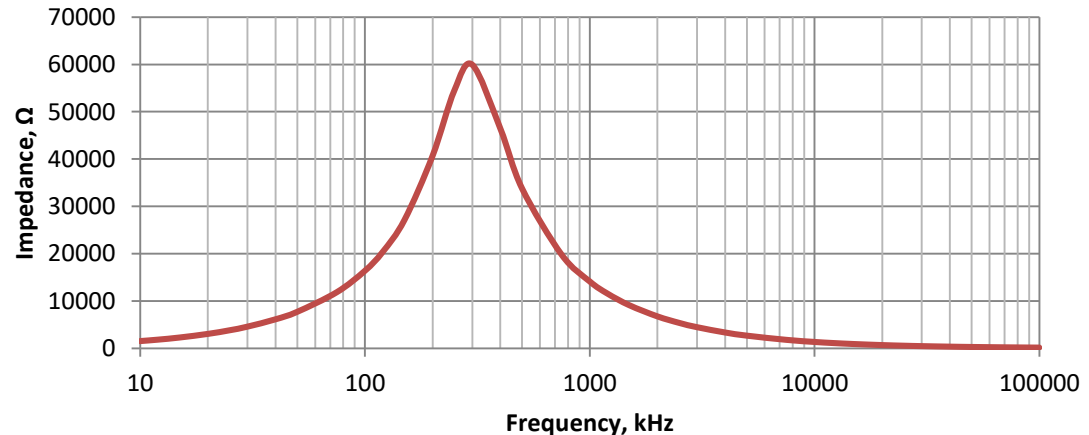
Part 3: Common-mode choke equivalent circuit

Here is the equivalent circuit of a common-mode choke (both windings connected in parallel) which is essentially a parallel RLC network:
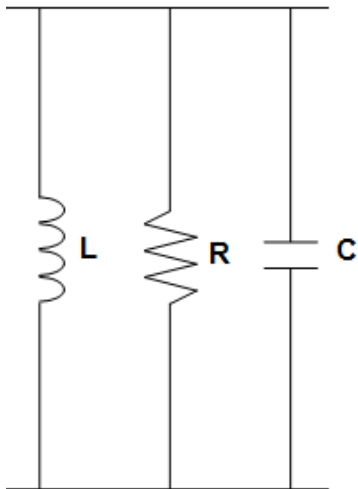
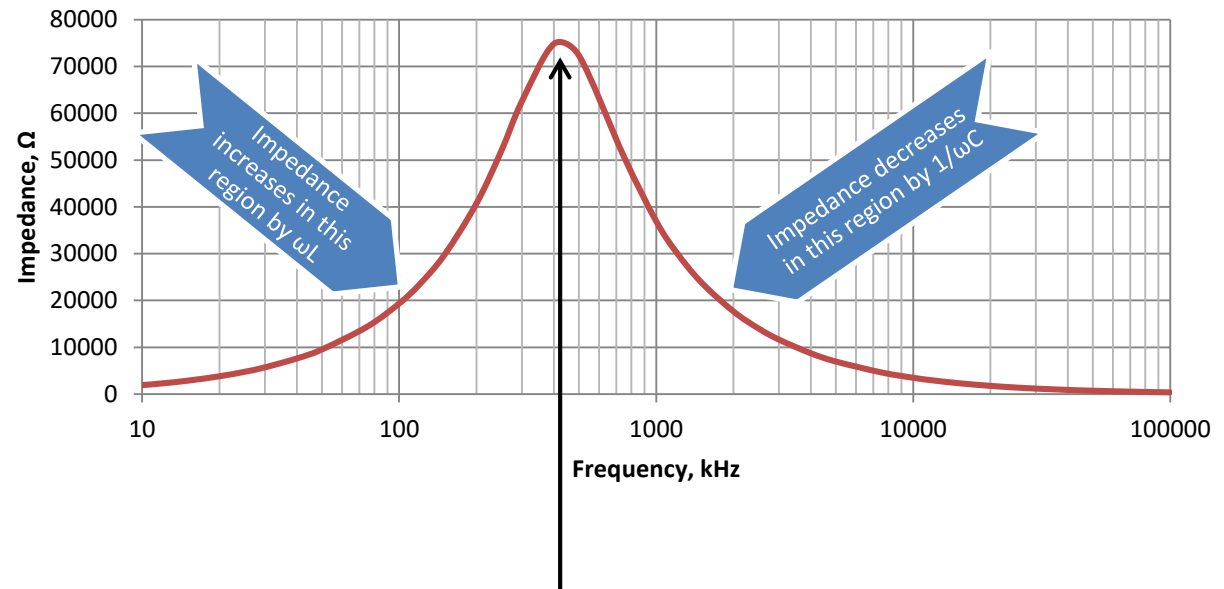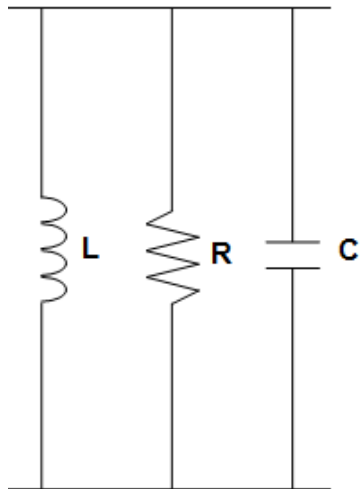The impedance of this parallel-resonant circuit is:

$$Z = \frac{1}{\sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{j\omega L} - j\omega C\right)^2}}$$

With the following plot of impedance versus frequency:

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Part 3: Common-mode choke equivalent circuit

Here is the equivalent circuit of a common-mode choke (both windings connected in parallel) which is essentially a parallel RLC network:
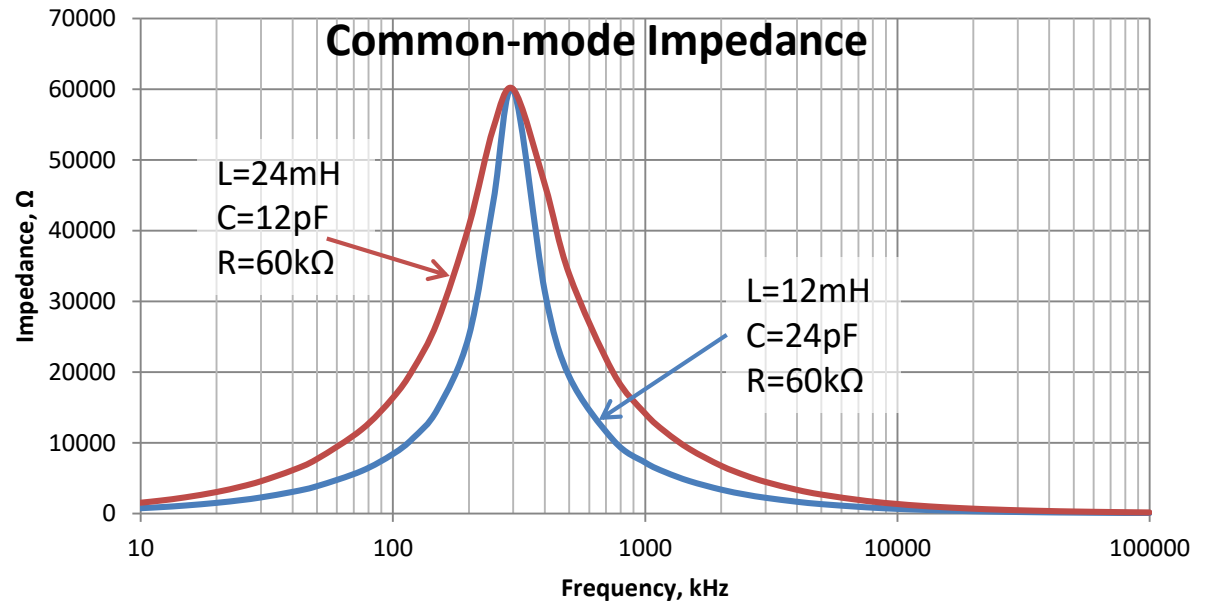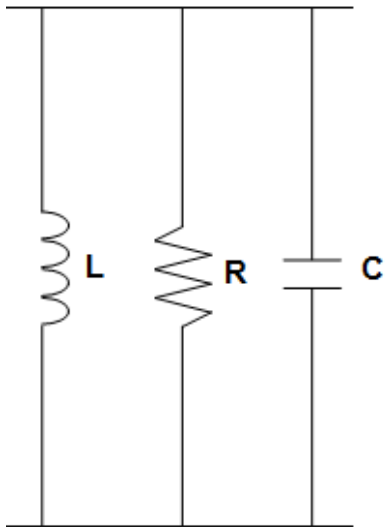

Impedance reaches a maximum at resonant frequency f_0 where X_L and X_C cancel leaving only the parallel resistance, R.

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

Part 3: Common-mode choke equivalent circuit

The width of the impedance peak is a function of the ratio L/C.
Here we see two CMCs with the same resonant frequency but one has twice as much inductance and half the capacitance:

So inductance plays a role in CMC performance but in conjunction with losses in the core as well as the choke's distributed capacitance.

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Part 4: Common-mode choke performance

Since the job of a common-mode choke is to present high impedance to common-mode signals more inductance is usually a good thing. Cores materials with high permeability (μ>10K) provide more inductance per turn than materials with lower permeability. Unfortunately high-perm cores generally have higher losses and thus lower peak impedance (lower Rparallel).

High-perm cores are generally suited to attenuate common-mode signals at or under 100kHz. Attenuation above 100kHz may require medium-perm core materials (5K>μ>7K) since their losses at those frequencies are generally lower than that of high-permeability materials.

Loss Factor V.S. Frequency

μ=10K

μ=7K

μ=5K

Loss Factor* 10⁻⁶

Frequency (kHz)

Test Core : T25*15*10
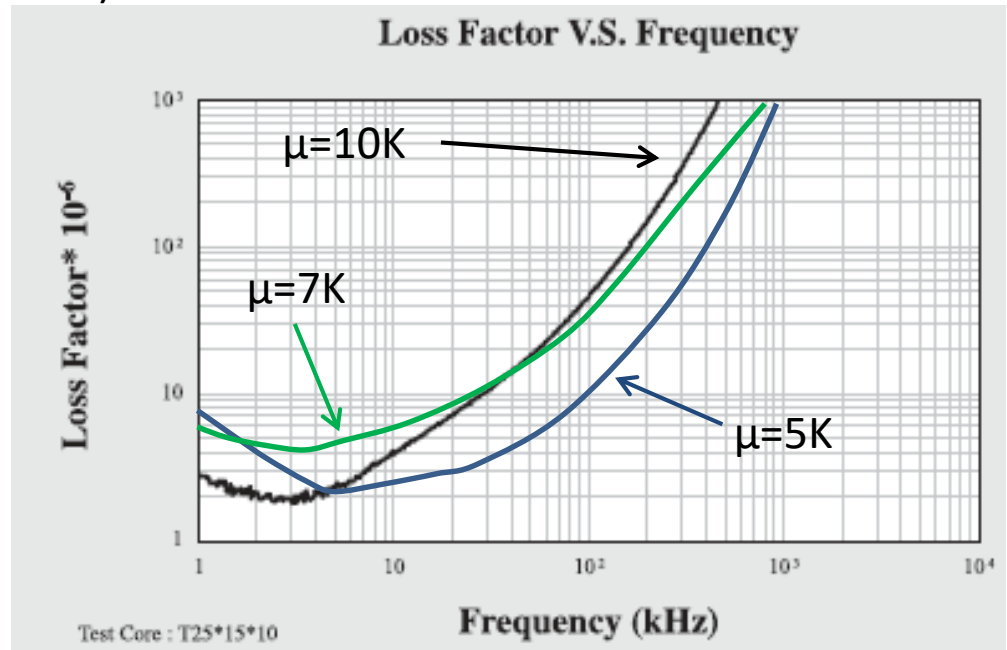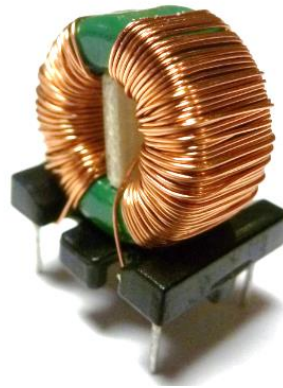
Part 4: Common-mode choke performance

For best performance we need to offset the added capacitance that normally comes with the higher turns counts.   One way to accomplish this is to break up the winding capacitance using multi-section bobbins or a special winding technique known as sector winding.
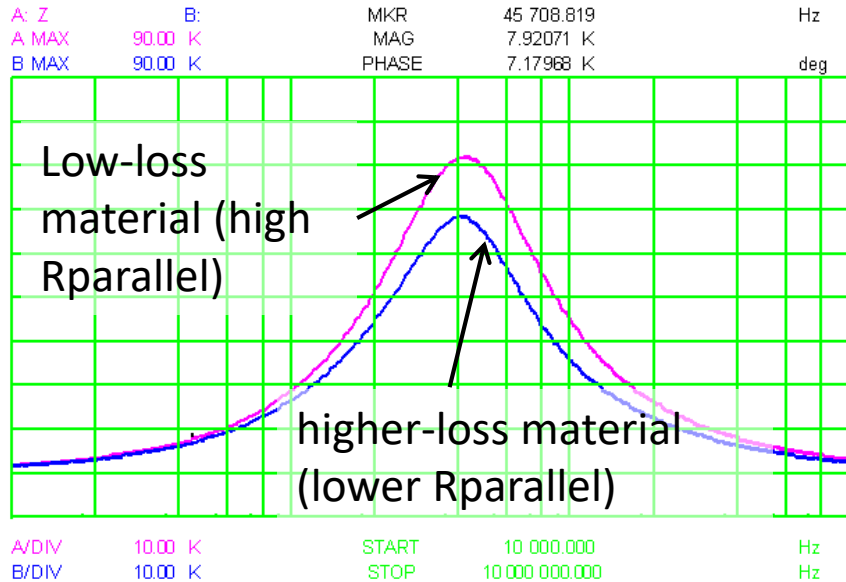
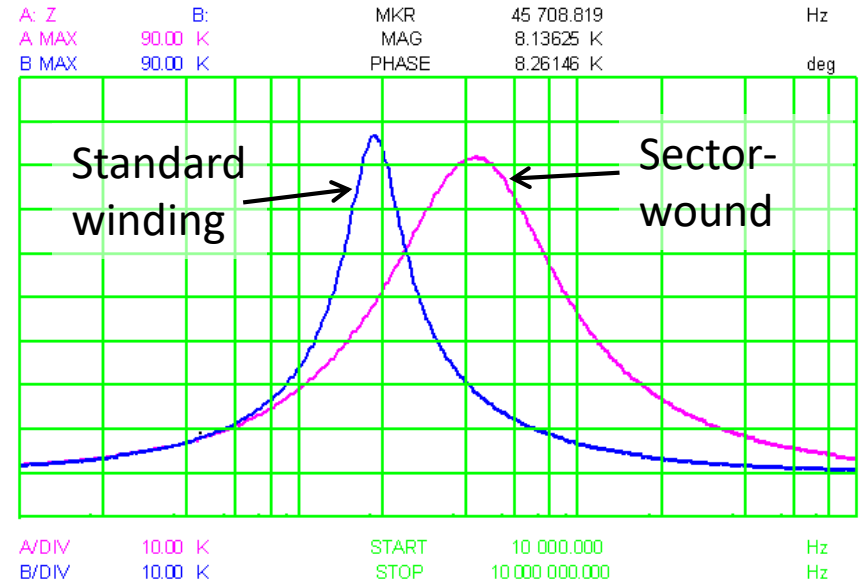Two-section bobbin

Four-section bobbin

Standard winding

Sector-wound CMC

Part 4: Common-mode choke performance

Low-loss and higher-loss core materials

Standard versus sector toroidal winding

Part 4: Common-mode choke performance

Impedance is the property that allows these devices to attenuate unwanted common-mode noise. The amount of attenuation in decibels can be predicted if the impedances on either side of the CMC are known. For sake of comparison the system impedance is many times assumed to be 50Ω.

$$A = 20 \cdot \log_{10} \left(\frac{R_g}{R_L + Z_{CMC}} \right)$$
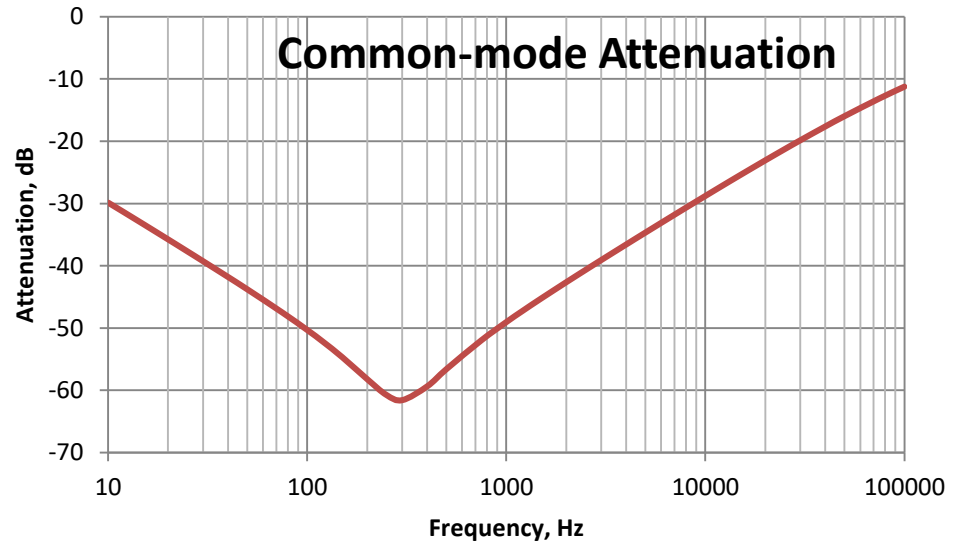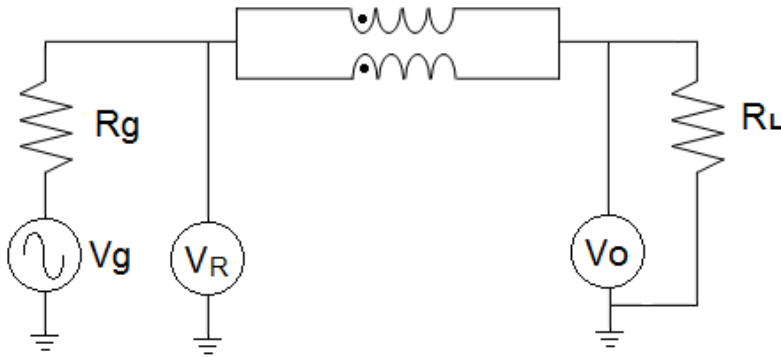
References:

www.minntronix.com/resources – A spreadsheet tool is available for download that helps predict impedance based on the equivalent circuit model. The spreadsheet was used to create some of the plots used in this presentation.

http://en.wikipedia.org/wiki/Choke_(electronics) Wikipedia entry describing chokes including common-mode.

Common-mode choke coils charaterization" (PDF), Konstantin Kostov and Jorma Kyyrä, from Proceedings of the 13th European Conference on Power Electronics and Application (2009).

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